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Auditory Steady State Responses in children and adolescents with severe to profound and steeply sloping sensorineural hearing loss

Potencial Evocado Auditivo de Estado Estável em crianças e adolescentes com perda auditiva neurossensorial de grau severo e profundo e descendente

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ABSTRACT

Purpose: To verify the correlation between the electrophysiological thresholds in Auditory Evoked Potential Steady State (ASSR) and behavioral thresholds obtained with pure tone audiometry in children and adolescents with severe to profound sensorineural hearing loss and steeply sloping hearing loss. **Methods:** Twenty subjects from both gender aged between five and 15 years-old were evaluated and divided into the following groups: 10 subjects with steeply sloping sensorineural hearing loss and 10 subjects with severe to profound sensorineural hearing loss. The subjects underwent pure tone audiometry, speech audiometry (SRT and SDT), acoustic immittance measures and ASSR. **Results:** In the group with steeply sloping hearing loss, the correlation was 0.68 and 0.94. In the group with severe to profound hearing loss, the correlation was 0.59 to 0.86. Mean differences between-ASSR and audiometry threshold were 1.4 and 7.5 dB in the group with steeply sloping hearing loss and -0.40 e-8.5 dB in the group with severe to profound hearing loss. **Conclusion:** There was a positive correlation between the electrophysiological and behavioral thresholds in children and adolescents with severe to profound hearing loss and steeply sloping hearing loss.

Keywords: Evoked potentials, Auditory; Hearing; Hearing loss; Child; Adolescent

RESUMO

Objetivo: Verificar a correlação entre os limiares eletrofisiológicos obtidos no Potencial Evocado Auditivo de Estado Estável (PEAEE) e os limiares comportamentais obtidos com audiometria tonal liminar, em crianças e adolescentes com perda auditiva neurossensorial de grau severo e profundo e perda auditiva de configuração descendente. **Métodos:** Foram avaliados 20 indivíduos, de ambos os gêneros, com idades entre 5 e 15 anos, distribuídos nos seguintes grupos: 10 indivíduos com perda auditiva neurossensorial descendente (GD) e 10 indivíduos com perda auditiva neurossensorial horizontal de grau severo e profundo (GS). Os indivíduos foram submetidos à audiometria tonal liminar, logoaudiometria, medidas de imitância acústica e ao potencial evocado auditivo de estado estável, nas frequências de 500 Hz, 1000 Hz, 2000 Hz e 4000 Hz. **Resultados:** No grupo com perda descendente, a correlação foi de 0,68 a 0,94 e no grupo com perda auditiva de grau severo e profundo, a correlação foi de 0,59 a 0,86. As diferenças médias do limiar do PEAEE e do limiar da audiometria situaram-se entre 1,4 e 7,5 dB no grupo com perda descendente e entre -0,40 e -8,5 dB, no grupo com perda auditiva de grau severo e profundo. **Conclusão:** Houve correlação positiva entre os limiares eletrofisiológicos e comportamentais nos grupos de crianças e adolescentes com perda auditiva neurossensorial horizontal de grau severo e profundo e descendente.

Descritores: Potenciais evocados auditivos; Audição; Perda auditiva; Criança; Adolescente

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INTRODUCTION

Due to implementation of hearing-health programs, early diagnosis of hearing loss has been most common, providing appropriate intervention. Hearing impairment causes many difficulties, since their effect on communication, until impact on psycho-social, cognitive, language and learning developments. To be able to proceed appropriately, the correct and accurate diagnosis is essential.

To establish the degree of hearing loss and audiometric configuration in neonates, however it is only possible by electrophysiological evaluation, which does not depend on the cooperation of the subject to obtain the response to stimuli and allows evaluation of specific frequencies by the auditory brainstem response (ABR) with *tone burst*, as well as the response obtained in auditory steady state response (ASSR). Thus, the applicability of the ASSR in early audiological diagnosis has been emphasized in the literature[1-11]. The easy and practical registrations in identifying the ASSR responses, using statistical analysis, are important aspects of this procedure[1]. The use of ASSR allowed determining the electrophysiological thresholds at 500-4000 Hz, which is information of essential importance in the selection and fitting of hearing aids.

According to the literature, the ASSR has potential for the prediction of hearing thresholds in children with different degrees of hearing loss, being highlighted as a complementary tool in the evaluation.

The ASSR for predicting behavioral hearing thresholds not yet part of the clinical assessment protocol for all services. However, some studies mention the presence of correlation between electrophysiological and behavioral thresholds, especially in subjects with severe to profound hearing loss[3,5,7,12-18]. In most studies, the selected sample consisted of adults. There are few studies with children and adolescents.

The aim of this study was to verify the correlation between the electrophysiological thresholds in Auditory Steady State Response (ASSR) and behavioral thresholds obtained with pure tone audiometry in children and adolescents with severe to profound sensorineural hearing loss and steeply sloping hearing loss.

METHODS

The study was an observational cross-sectional analytical approved by the Ethics Committee in Research of the Universidade Federal de São Paulo (UNIFESP) (n ° 0669/11). All parents of children and adolescents were informed about the procedures to be performed and signed an informed consent before study participation. The literate adolescents were also informed of the procedures and signed Consent.

The sample consisted of 20 subjects of both genders, aged between 5 and 15 years, divided into two groups: Group 1: 10 subjects with steeply sloping sensorineural hearing loss (GD); Group 2: 10 subjects with flat severe to profound sensorineural hearing loss (GS).

The inclusion criteria were age between 5 and 15 years, tympanogram type A bilaterally[19], and absence of otoacoustic emissions (transient and distortion product). The age was determined by presenting consistent response on audiometry. Thus, the values of the evaluation were reliable for comparison with the electrophysiological thresholds. The subjects with conductive and neurological disorders were excluded from the study.

All subjects underwent anamnesis, pure tone audiometry, acoustic immittance measures and electrophysiological hearing evaluation by the ASSR. The same examiner performed all procedures.

The audiometry was performed in a soundproof booth with MA-41 audiometer and use of supra-aural TDH-39. The research of hearing thresholds was conducted at frequencies 250-8000 Hz and subjects were asked to raise their hands when the sound stimuli were heard, even at low intensity. The hearing threshold was searched using the descending-ascending technique at intervals of 10 dB (descending) and 5 dB (ascending). It was considered as the threshold of audibility the lowest intensity level which the patient responded to 50% of the presentations of the sound stimulus.

The degree of hearing loss was classified by analyzing the mean of air conduction thresholds at frequencies of 500, 1000 and 2000 Hz[20]. Hearing loss was considered severe when the mean was between 71 and 90 dB and profound hearing loss, the mean greater than or equal to 91 dB. The configuration of the flat audiogram was classified when there was a difference of 5 dB between the thresholds at different frequencies and steeply sloping, when there was a difference 5-20 dB per octave toward the octave frequencies[21].

It was considered Tympanogram type A when the maximum compliance peak was between +100 and -100 daPa and the volume of the middle ear, between 0.3 and 1.6 ml[19].

The auditory steady state response was performed with the Smart EP device, manufactured by Intelligent Hearing Systems®. The evaluation was performed in a soundproof and electrically treated room. The subjects were accommodated in comfortable recliner armchair and they were instructed to remain quiet, avoiding movements, especially the muscles of the head and neck, and myogenic artifacts. Before starting the tests, the subjects' skin was prepared with the aid of an abrasive paste and electrodes positioned so that the record was performed ipsilateral to the stimulated ear, keeping impedance <5 kΩ. The arrangement of the electrodes was as follows: M1, Fz and M2: (-) tested ear, (+) forehead, (ground) untested ear. Insert earphones ER-3B, adapted to the external acoustic meatus (EAM) using disposable foam plugs, presented the acoustic stimuli. The evaluation was conducted in natural sleep, without the use of sedation. The stimulation was monaural and stimulus presentation was mixed (multifrequency, at the beginning of the examination and a single frequency near the threshold).

Table 1. Mean values of electrophysiological and behavioral thresholds at frequencies 500-4000 Hz, by ear, in the group with sloping hearing loss

Ear	Frequency (kHz)	n	Mean ET	SD ET	Median ET	Mean BT	SD BT	Median BT
Right	0.5	10	29.50	14.23	29.0	27.0	15.13	25.0
	1	10	44.50	18.77	39.0	38.0	23.94	37.5
	2	10	70.50	17.0	67.0	65.5	17.87	62.5
	4	10	71.20	18.02	68.0	67.0	17.03	62.5
Left	0.5	10	36.50	18.77	36.5	32.5	18.45	25.0
	1	10	48.50	19.92	44.0	41.0	21.06	40.0
	2	10	70.00	17.98	74.5	67.5	18.89	62.5
	4	10	73.40	19.86	73.5	72.0	19.47	65.0

Note: ET = electrophysiological thresholds; BT = behavioral thresholds; SD = standard deviation

The electrophysiological threshold testing was performed with the descending technique (10 dB) and ascending (5 dB). The maximum intensity of the device was 117 dB SPL. The electrophysiological thresholds in dB SPL were obtained and converted to dB HL (dB cg NA), the equipment itself. The correction values were -26 dB for 500 Hz, -11 dB at 1000 Hz, 2000 Hz and -13 dB to -19 dB 4000 Hz.

The ASSR was detected automatically by comparing the signal amplitude and noise amplitude in the rate of presentation. These responses were divided into signal and noise, using a statistical F test. The response was considered present when the ratio of signal and noise was greater than or equal to 6.13 dB microvolts larger than 0.0125 µV response as electrical noise lower than 0,05 µV and less than or equal residual noise 0.07 µV. The statistical analysis was performed every 20 scans, using the maximum production of 400 scans using a filter 30-300 Hz. The criterion to stop the recording of the examination was the presence or absence of response, with the residual noise below 0.70 µV (parameter suggested by the technical manual for the equipment). In cases where the noise did not reach that limit by 400 scans, the test was restarted.

The stimulus was a *tone pipe*, 100% modulated in amplitude with carrier frequencies 500-4000 Hz, the modulation frequencies in the right ear - 79, 87, 95, 103 Hz - and the left ear - 77, 85 , 93 Hz and 101 -, respectively.

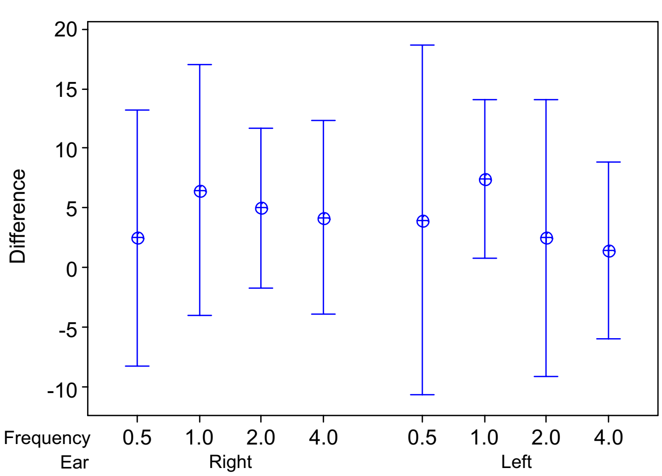
Despite use of different transducers in this study to obtain the behavioral thresholds (supra-aural TDH-39) and electrophysiological thresholds (insert earphones ER-3B), did not fix the thresholds to insertion earphone in behavioral audiometry, since that the correction factors for frequencies from 500 Hz to 4000 Hz range between 0 and 2 dB[22]. Correction of 2 dB has not clinical validity, since that the threshold search is performed with 5 dB increments.

For statistical analysis of this study, descriptive statistics (mean, standard deviation, median, minimum and maximum) of electrophysiological and behavioral and Pearson linear correlation test thresholds were performed, which was used to verify the correlation between electrophysiological and behavioral thresholds of ASSR audiometry.

RESULTS

The mean values of the electrophysiological thresholds in ASSR and behavioral hearing thresholds in pure tone audiometry at frequencies 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, were established by ear, considering the possibility of asymmetrical hearing loss. The mean hearing thresholds found in subjects with steeply sloping sensorineural hearing loss are presented in Table 1.

The greater differences found between the electrophysiological threshold and behavioral hearing thresholds in subjects with steeply sloping sensorineural hearing loss were the frequency of 1000 Hz (Figure 1).



RE: 500Hz: 2.5±10.8; 1000Hz: 6.5±10.61; 2000Hz: 5.0±6.75;4000Hz: 4.2±8.18
LE: 500Hz: 4.0±14.72; 1000Hz: 7.5±6.69; 2000Hz: 2.5±11.65; 4000Hz: 1.4±7.43

Figure 1. Mean ± 1 standard deviation of differences in dB HL, by frequency and ear – steeply sloping hearing loss

As for the correlation values obtained using Pearson correlation in subjects with steeply sloping sensorineural hearing loss, there was a significant positive correlation at frequencies of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz (Table 2).

In subjects with severe to profound sensorineural hearing loss, the mean behavioral thresholds were higher than the

Table 2. Fitted regression line and observed values of the Pearson correlation coefficient between the variables, the ASSR electrophysiological thresholds and behavioral hearing threshold by frequency and ear - steeply sloping hearing loss

Frequency (kHz)	Right ear			Left ear		
	Fitted line	R	p-value	Fitted line	R	p-value
0.5	Threshold A = 4.1 + 0.776 ASSR	0.730	0.016*	Threshold A = 7.8 + 0.676 ASSR	0.687	0.028*
1	Threshold A = -13.3 + 1.15 ASSR	0.905	<0.001*	Threshold A = -7.6 + 1.00 ASSR	0.948	<0.001*
2	Threshold A = -3.1 + 0.973 ASSR	0.926	<0.001*	Threshold A = 8.6 + 0.842 ASSR	0.801	0.005*
4	Threshold A = 6.9 + 0.843 ASSR	0.893	0.001*	Threshold A = 5.18 + 0.91 ASSR	0.929	<0.001*

In the fitted line, the response variable is the threshold in the Auditory and the explanatory variable is the ASSR threshold
*Significant values (p<0.05) – Pearson correlation coefficient (r)
Note: ASSR = Auditory Steady State Responses

Table 3. Mean values of electrophysiological and behavioral thresholds at frequencies 500-4000 Hz, by ear, in the group with severe to profound sensorineural hearing loss

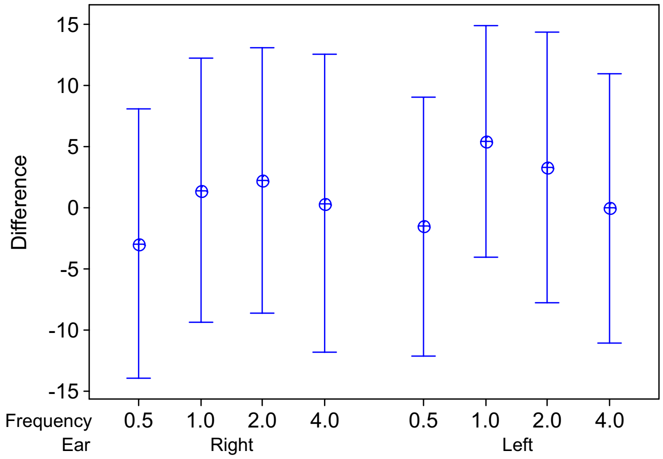
Ear	Frequency (kHz)	n	Mean ET	SD ET	Median ET	Mean BT	SD BT	Median BT
Right	0.5	10	81.0	14.53	88.5	89.5	17.71	89.5
	1	10	94.0	18.01	100.0	98.5	15.99	95.0
	2	10	93.2	16.57	95.5	100.0	17.16	95.0
	4	10	94.1	9.69	97.0	102.5	19.76	105.0
Left	0.5	10	81.8	11.82	76.5	87.5	15.50	85.0
	1	10	96.6	12.36	96.5	97.0	16.19	95.0
	2	10	97.1	13.97	102.0	100.5	17.39	97.5
	4	10	93.7	18.76	99.5	99.6	19.84	102.5

Note: ET = electrophysiological thresholds; BT = behavioral thresholds; SD = standard deviation

electrophysiological in all analyzed frequencies - 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz (Table 3).

As for the mean values of the differences between electrophysiological thresholds and behavioral hearing thresholds in subjects with flat severe to profound sensorineural hearing loss, the greater differences occurred at frequencies of 500 Hz and 4000 Hz and the lowest, at 1000 Hz (Figure 2).

In subjects with flat severe to profound sensorineural hearing loss was a significant positive correlation at frequencies 500 Hz, 1000 Hz and 2000 Hz in the right ear and the frequencies of 1000 Hz and 2000 Hz in the left ear (Table 4).



RE: 500Hz: -8.5±10.07; 1000Hz: -4.5±8.96; 2000Hz: -6.80±12.73;4000Hz: -8.40±16.03
LE: 500Hz: -5.70±9.72; 1000Hz: -0.40±9.24; 2000Hz: -3.40±11.88; 4000Hz: -5.9±12.95

Figure 2. Mean ± 1 standard deviation of differences in dB HL, by frequency and ear - severe to profound hearing loss

DISCUSSION

As for the group with steeply sloping sensorineural hearing loss, it was observed that the electrophysiological thresholds were higher than behavioral thresholds, especially in the frequencies 2000 and 4000 Hz. The mean differences were between 1.4 and 7.5 dB lower those obtained in international studies conducted with adult population. Study of 11 workers exposed to noise, with steeply sloping sensorineural hearing loss, found differences between 12 and 17 dB HL[23]. Another study also had greater differences in relation to this study, between 5 and 18 dB HL[24]. However, the sample included a wide age range, including adults and seniors 21-79 years. ASSR studies in adolescents with steeply sloping sensorineural loss were not found in the literature, which values the findings of this work.

The presence of higher electrophysiological thresholds was expected, since that the studies analyzed, we used the electrophysiological evaluation, obtained electrophysiological thresholds 10-15 dB higher compared to behavioral thresholds. The distance between generating sites and surface electrodes

Table 4. Fitted regression line and observed values of the Pearson correlation coefficient between the variables, the ASSR electrophysiological thresholds and behavioral hearing threshold by frequency and ear – severe to profound hearing loss

Frequency (kHz)	Right ear			Left ear		
	Fitted line	r	p-value	Fitted line	r	p-value
0.5	Threshold A = 8.29 + 1.003 ASSR	0.823	0.003*	Threshold A = 3.9 + 1.02 ASSR	0.779	0.008#
1	Threshold A = 26.1 + 0.771 ASSR	0.868	0.001*	Threshold A = -7.2 + 1.08 ASSR	0.823	0.003*
2	Threshold A = 30.9 + 0,741 ASSR	0.715	0.020*	Threshold A = 11.8 + 0.913 ASSR	0.734	0.016*
4	Threshold A = -11.4 + 1,21 ASSR	0.594	0.070#	Threshold A = 22.6 + 0.821 ASSR	0.776	0.008#

In the fitted line, the response variable is the threshold in the Auditory and the explanatory variable is the ASSR threshold
*Significant values ($p<0.05$) – Pearson correlation coefficient (r)
#Trend toward significance
Note: ASSR = Auditory Steady State Responses

to capture the response (potential far field) is one of the explanations for the occurrence of this difference due to the smaller amplitude of response that needs to be extracted from the background noise.

In children and adolescents with steeply sloping sensorineural hearing loss, there was a strong correlation between electrophysiological and behavioral thresholds at frequencies from 500 Hz to 4000 Hz in the right ear, and 1000 Hz to 4000 Hz in the left ear. These findings agree with the study that also found a strong correlation in the frequencies of 500 Hz to 4000 Hz, in workers exposed to noise[23]. Study in 29 children with steeply sloping hearing loss found a strong correlation of 500 Hz to 2000 Hz and moderate correlation in the frequency of 4000 Hz[25]. It was observed the worst correlation in the frequency of 500 Hz, which can be explained by the electrophysiological noise and/or environmental interferences in the low frequencies. One of the factors responsible for the presence of the worst responses at 500 Hz is due to cochlear tonotopia (bass located in the apical portion of the cochlea), resulting in decreased amplitude of the response at this frequency, located in the cochlear apical part[1].

Otherwise, the group with flat severe to profound sensorineural hearing loss behaved differently, this is the mean and median were higher in audiometry, compared to ASSR. Electrophysiological mean thresholds were between 81 and 97 dB HL and behavioral, between 87.5 and 102.5 dB HL. Study in children and adolescents with severe to profound hearing loss recorded electrophysiological thresholds between 91 and 96 dB HL and behavioral thresholds between 84 and 93 dB HL[26]. Thus, despite similarity of the electrophysiological thresholds in both studies, there was disagreement regarding the comparison of the two procedures. On the other hand, a study in adults also achieved better electrophysiological thresholds compared with behavioral, agreeing with the findings of this study[27].

The presence of smaller ASSR thresholds, with respect to the thresholds of audiometry in severe to profound hearing loss, could be assigned to occurrences of artifacts resulting from strong stimulation, regarded as electrical artifacts caused by aliasing effect (overlapping signal, the conversion of analog signal to digital)[28]. Other studies suggest the influence of vestibular evoked myogenic potentials, as these appear in response to auditory stimuli of high intensity[28,29].

The mean differences in the group with severe to profound flat sensorineural hearing loss ranged between -0.40 and -8.5 dB. Other studies have found greater differences between 4 and 6 dB, severe to profound hearing loss in children[26]. A study of adults was found differences of -8 to -11 dB with severe to profound hearing loss[27], similar to those obtained in this study. Such differences in results can be attributed to the use of different equipment and protocols, as they were similar to values in the study using the same equipment and protocol[27]. Thus, the ASSR thresholds obtained in losses of severe to profound hearing loss could be underestimated. To minimize such effects, it is recommended not to search the thresholds at all frequencies simultaneously, which reduces the sound pressure level and the possibility of myogenic vestibular responses. In addition, new technologies are being studied for the reduction of electrical devices[28,29].

In people with severe to profound flat sensorineural hearing loss, there was a strong correlation between the electrophysiological threshold and behavioral thresholds at frequencies 500-2000 Hz in the right ear and 500-4000 Hz in the left ear. Only the frequency of 4000 Hz in the right ear, there was a moderate correlation. In a similar study in subjects 10-15 years with severe to profound hearing loss, the strongest correlation was obtained only at 1000 Hz, with moderate correlations in the remaining frequencies[26]. Another study, with subjects between 5 and 74 years, found a correlation of 0.91 with the severe to profound hearing loss[30].

The strong correlation between electrophysiological and behavioral thresholds obtained in this study shows good applicability of ASSR in the early diagnosis of hearing impairment process, especially in severe to profound flat sensorineural sensorineural hearing loss and steeply sloping hearing loss. Thus, children who still do not respond on pure tone audiometry, which is the gold standard for determining the psychoacoustic threshold, can benefit from the use of ASSR, which has good reliability for setting the thresholds, contributing effectively to adapt the hearing aids in the first months of life.

CONCLUSION

There was a positive correlation between electrophysiological and behavioral thresholds in groups of children and adolescents with severe to profound flat sensorineural hearing loss and steeply sloping hearing loss, demonstrating the clinical applicability of ASSR in audiological diagnosis.

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